Description

INTEGRATED COOLING SYSTEM

U.S. Government Rights

[01] This invention was made with government support under the terms of Contract No. DE-FC04-2000AL67017 awarded by the Department of Energy. The government may have certain rights in this invention.

Claim for Priority

[02] This application claims the benefit of U.S. Provisional Application No. 60/458,460, filed March 28, 2003.

Technical Field

[03] The present invention relates generally to a cooling system, and more particularly to an integrated main engine and auxiliary power unit cooling system.

Background

[04] Work machines, including on-highway vehicles, have a main power source for moving the work machine. The main power source may also be used to power electrical accessories including, for example, an air conditioning system, a heater, lights, and various other accessories. The main power source may be an engine such as a diesel engine, a gasoline engine, a natural gas engine, or any other type of engine that may be used for powering a work machine.

[05] The main power source must be running to power the electrical accessories of the work machine with the main power source. This may lead to idling the main power source for extended periods. For example, while parked, a machine operator may have to idle the main power source to power the air conditioner, a TV, or other appliances. Such extended periods of idling can result in high fuel consumption, increased emissions, and increased wear of the main power source.

[06] U.S. Patent No. 5,528,901 (the '901 patent), issued to Willis on June 25, 1996, describes the use of an auxiliary power unit (APU) to meet the power demands of the work machine without necessarily idling the main power source for extended periods. The APU is a secondary engine that produces power, which may be used to provide for the accessory electrical loads of the work machine. The APU may allow the main work machine power source to be turned off when the APU power generating capacity is sufficient to meet the demands of the accessory electrical loads of the work machine.

[07] The APU described in the '901 patent may also aid in cold starting situations. Specifically, the APU may be used to circulate coolant, warmed by an exhaust heat exchanger in the APU, through the main power source prior to starting the main power source. The warm coolant circulating through the main power source increases main power source temperature, which may improve startability.

[08] Although the APU of the '901 patent may alleviate some of the difficulty associated with cold starting and may provide additional power for the work machine, the cooling system of the '901 patent may be inadequate for cooling more complex engine systems having additional components. In addition, the cooling system of the '901 patent does not disclose a means for controlling the temperature of the coolant within the cooling system as it circulates through various portions of the cooling system, or a method of removing heat from the coolant.

[09] The present invention is directed to overcoming one or more of the problems set forth above.

Summary of the Invention

[10] In one aspect, the present disclosure is directed to a power system that includes an engine having a first coolant circuit. The power system has a torque converter operatively connected to the engine and in fluid communication with the first coolant circuit. The power system also includes at least one auxiliary power unit having a second coolant circuit. The first coolant circuit is in fluid communication with the second coolant circuit.

[11] In another aspect, the present disclosure is directed to a method of cooling a power system. The method comprises operating an auxiliary power unit having a cooling circuit and pumping coolant through the auxiliary power unit cooling circuit. The method also includes directing the coolant from the auxiliary power unit cooling circuit to a cooling circuit of a main engine and directing the coolant from the main engine cooling circuit to a torque converter.

Brief Description of the Drawings

[12] Fig. 1 is a diagrammatic illustration of a work machine having an integrated cooling system according to an exemplary embodiment of the present invention.

[13] Fig. 2 is a schematic illustration of the integrated cooling system according to an exemplary embodiment of the present invention.

[14] Fig. 3 is a schematic illustration of a control system for the integrated cooling system according to an exemplary embodiment of the present invention.

Detailed Description

[15] Fig. 1 illustrates a work machine 10 including an integrated cooling system 12 and a traction device 13. The integrated cooling system 12 fluidly connects a main engine 14 with an auxiliary power unit (APU) 16, a work machine heating system 18, a torque converter 20, and a starter/generator 22. Main engine 14 may be, for example, a diesel engine, a gasoline engine, a natural gas engine, a fuel cell, or any other type of engine that includes a cooling system. APU 16 may also be a diesel engine, a gasoline engine, a natural gas engine, or another power source having a cooling system. As illustrated in Fig. 2, integrated cooling system 12 may be connected to main engine 14, torque converter 20, and starter/generator 22 via a first coolant circuit 24, to APU 16 via a second coolant circuit 26, and to work machine heating system 18 via a third coolant circuit 28.

[16] First coolant circuit 24, connected to main engine 14, may include a pump 30, an oil cooler 32, a first temperature sensor 34, a first thermostat 36, a radiator 38, a fan 40, and a second temperature sensor 42.

[17] Pump 30 may be electrically driven, mechanically driven , or driven in any other manner known in the art. Pump 30 may be fluidly connected to oil cooler 32 via a fluid passageway 44 and configured to cause the coolant within first coolant circuit 24 to flow.

[18] Oil cooler 32 may be in fluid communication with an engine lubrication system and configured to cool engine oil. Oil cooler 32 may be any type of liquid-to-liquid heat exchanger such as, for example, a flat plate heat exchanger, or a tube and bundle heat exchanger. Oil cooler 32 may be fluidly connected to main engine 14 via a fluid passageway 46.

[19] The coolant within first coolant circuit 24 may be routed through a cylinder block, a cylinder head, a cylinder liner, or through any other structure associated with main engine 14 to provide main engine cooling. Main engine 14 may be fluidly connected to first temperature sensor 34 and first thermostat 36 via a fluid passageway 48.

[20] First temperature sensor 34 may be configured to generate a signal indicative of the temperature of the coolant entering first thermostat 36. First thermostat 36 may be a mechanical device that is movable from a first position where fluid flows relative to first thermostat 36 to a second position where the fluid is blocked from flowing relative to first thermostat 36. First thermostat 36 moves from the first position to the second position when coolant with a temperature above a predetermined value is in fluid communication with first thermostat 36. Other components for allowing fluid to flow may be used in place of first thermostat 36, such as a solenoid valve, a throttle valve, or other means known in the art. First thermostat 36 may be in fluid communication with radiator 38 via fluid passageway 50.

[21] Radiator 38 may be a liquid-to-air heat exchanger configured to expel heat from first coolant circuit 24 as coolant flows through radiator 38. Radiator 38 may work in conjunction with fan 40, which is configured to blow ambient air across radiator 38. Radiator 38 may be in fluid communication with second temperature sensor 42 and pump 30 via a fluid passageway 52. Second temperature sensor 42 may

be configured to generate a signal indicative of the temperature of the coolant exiting radiator 38.

[22] As described above, torque converter 20 and starter/generator 22 may be fluidly connected to first coolant circuit 24. Torque converter 20 may be selected from a variety of devices known in the art for transmitting and amplifying torque. Starter/generator 22 may be a motor and generator combined into a single unit. Starter/generator 22 may be configured to either apply torque to main engine 14 during a motoring mode or remove torque from main engine 14 during a generating mode. Starter/generator 22 may also be configured to include a starter and a generator as stand alone units for motoring main engine 14 and generating power. Torque converter 20 and starter/generator 22 may be fluidly connected to first coolant circuit 24 via a fluid passageway 54 and a fluid passageway 56. A check valve 57 may be disposed in fluid passageway 56 to provide for one-directional flow through torque converter 20 and starter/generator 22.

[23] Second coolant circuit 26, connected to APU 16, may include a pump 58 and a second thermostat 60. Pump 58 may be electrically driven, mechanically driven, or driven in any other manner known in the art. Coolant within second coolant circuit 26 may be pumped through a cylinder block, a cylinder head, a cylinder liner, or through any other structure associated with APU 16 for providing APU cooling. APU 16 may be fluidly connected to second thermostat 60 via a fluid passageway 62 and to pump 58 via a fluid passageway 64.

[24] Third coolant circuit 28, connected to work machine heating system 18, may include an operator cabin heat exchanger 66, a sleeping cabin heat exchanger 68, an operator cabin temperature sensor 70, a sleeping cabin temperature sensor 72, an operator cabin water valve actuator 74, and a sleeping cabin water valve actuator 76.

[25] Heated coolant may be directed to operator cabin heat exchanger 66 and sleeping cabin heat exchanger 68 via a fluid passageway 77. Operator cabin heat exchanger 66 and sleeping cabin heat exchanger 68 may be fluid-to-air heat exchangers configured to transfer heat to ambient air blown across the respective heat exchangers. The heated air may then be fed into an operator cabin and a sleeping

cabin. Operator heat exchanger 66 and sleeping cabin heat exchanger 68 may be connected to operator water valve actuator 74 and sleeping cabin water valve actuator 76 via fluid passageways 78 and 80, respectively.

[26] First, second, and third coolant circuits 24, 26, and 28 may be fluidly connected to transfer fluid between the three coolant circuits. First coolant circuit 24 may be connected to second coolant circuit 26 via a fluid passageway 82 and to third coolant circuit 28 via a fluid passageway 84. A check valve 86 may be disposed within fluid passageway 84 to provide for one-directional flow of coolant from first coolant circuit 24 to third coolant circuit 28. Second coolant circuit 26 may be connected to third coolant circuit 28 via fluid passageways 87 and 88. A check valve 89 may be disposed within fluid passageway 87 to provide for one-directional flow of coolant from second coolant circuit 26 to third coolant circuit 28.

[27] Fig. 3 illustrates a control system 90 for integrated cooling system 12. Integrated cooling system 12 may include a controller 92 in communication with first temperature sensor 34, second temperature sensor 42, operator cabin temperature sensor 70, sleeping cabin temperature sensor 72, pump 30, fan 40, pump 58, operator cabin water valve actuator 74, and sleeping cabin water valve actuator 76. Controller 92 may be operable to receive a signal indicative of a coolant or an air temperature and to change the operation of water valve actuators 74 and 76, pumps 30 and 58, and/or fan 40 in response to the signal.

Industrial Applicability

[28] The present invention may be applicable to any power system having a main engine 14 and at least one APU 16. For these power systems, integrated cooling system 12 may allow for improved cold starting, reduced emissions, extended engine life, and reduced cost.

[29] As APU 16 is operated, pump 58 may be actuated to circulate the coolant within second coolant circuit 26 through APU 16 to cool the engine block, the cylinder head, the cylinder liner, and any other components requiring cooling. During initial operation of APU 16, following startup, the temperature of the cylinder block, cylinder head, and/or cylinder liner, may be too low to support efficient combustion

within APU 16. In this situation, pump 58 may be deactivated to stop the flow of coolant through APU 16 until the temperature of APU 16 is within a desired range that may support safe and efficient combustion.

[30] While the temperature of the coolant in second coolant circuit 26 is within the desired operating range or below the desired operating range, second thermostat 60 may remain closed. As operation of APU 16 continues, the temperature of the coolant within second coolant circuit 26 may exceed the desired temperature range. In this situation, second thermostat 60 may open to allow the coolant from second coolant circuit 26 to join the coolant from first coolant circuit 24. As second thermostat 60 opens to allow fluid from the first and second coolant circuits 24, 26 to combine, pump 30 and pump 58 may be selectively actuated alone or together to cause the coolant to flow throughout both circuits.

[31] Coolant from second coolant circuit 26 may be allowed to circulate through first coolant circuit 24 for a variety of reasons. First coolant circuit 24 may act as a heat sink and/or heat exchanger used to cool second coolant circuit 26. The ability to circulate the coolant from second coolant circuit 26 through first coolant circuit 24 may allow for a reduction of components within work machine 10 because APU 16 would no longer require its own heat rejection components. The reduction in components may result in a reduction in cost of the work machine 10. In addition, the warmed coolant from APU 16 circulating through main engine 14 may facilitate starting of main engine 14 during cold conditions.

[32] As the warm coolant from APU 16 enters main engine 14, the coolant may be directed through one of two paths. If the temperature of the entering coolant is below a predetermined level, first thermostat 36 may remain closed, and the coolant may be directed through pump 30, oil cooler 32, and into main engine 14. The coolant may flow through the cylinder block, the cylinder head, the cylinder liner, and/or any other components of main engine 14. If the temperature of the entering coolant is above the predetermined level, first thermostat 36 may open to allow coolant to flow through radiator 38 before entering pump 30.

[33] Control system 90 may change the operation of fan 40 and pump 30 to regulate coolant temperature within first coolant circuit 24. As the coolant within first

coolant circuit 24 circulates, first and second temperature sensors 34 and 42 may send signals to controller 92 indicative of the temperature of the coolant entering and exiting first thermostat 36 and/or radiator 38. Controller 92 may then change the operation of pump 30 and fan 40 (i.e., engaging, disengaging, and speed modifying) to maintain the temperature of the coolant in first coolant circuit 24 within a desired APU operating range or within a desired main engine operating and/or starting range, depending on which engine is operating and what mode of operation the engine is in.

[34] Additional components may also be in fluid communication with first coolant circuit 24. Main engine 14 may include a liquid-cooled torque converter 20 and a liquid-cooled starter/generator 22, which receive coolant directed from oil cooler 32 of first coolant circuit 24. The coolant flowing through torque converter 20 and starter/generator 22 may be returned to main engine 14 where the coolant either absorbs or rejects heat and begins the cycle anew.

[35] The first coolant circuit 24 and/or second coolant circuit 26 may be connected to an operator cabin and/or a sleeping cabin to reject heat. The heat may be used to warm the cabins, or may simply be rejected to third coolant circuit 28 without heating the cabins. Coolant from first and/or second coolant circuits 24, 26 may be directed to operator cabin heat exchanger 66 and/or sleeping cabin heat exchanger 68. As the warmed coolant is circulated through respective heat exchangers, one or more fans within the operator and/or sleeping cabin may be actuated to blow air across the heat exchangers to absorb heat and direct the heated air into the operator and sleeping cabins. Operator and sleeping cabin water valve actuators 74, 76 disposed within third coolant circuit 28 may be moved between a first position, where coolant is allowed to flow through third coolant circuit 28, and a second position, where coolant is blocked from flowing through third coolant circuit 28. By actuating the fans within the respective cabins, the first and second coolant circuits 24 and 26 may be used to supply heat to the cabins. In addition, even when the fans are not actuated, the coolant from the first and/or second coolant circuits 24, 26 may be circulated through the third coolant circuit 28 to use third coolant circuit 28 as a heat sink, whereby additional heat may be rejected from first and second coolant circuits 24, 26.

[36] Controller 92 may be operable to control the temperature within the operator and/or sleeping cabins. Controller 92 may be in communication with temperature sensors 70 and 72 and operable to move the water valve actuators 74, 76 between the first and second positions in response to a signal from temperature sensors 70, 72.

[37] The combined nature of the integrated cooling system 12 may allow for a reduction in the number of cooling components associated with a power system of work machine 10. For example, the disclosed system obviates the need for a separate cooling system associated with torque converter 20 and starter/generator 22, and the need for a separate radiator/fan combination for APU heat rejection. This may result in a decrease in cost of work machine 10. In addition, the warmed coolant from APU 16 may be used to facilitate starting of main engine 14 during cold conditions, which may result in reduced emissions, improved fuel efficiency, and extended main engine life.

[38] It will be apparent to those skilled in the art that various modifications and variations can be made to the disclosed integrated cooling system without departing from the scope of the invention. Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope of the invention being indicated by the following claims and their equivalents.